

Research Article

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Effect of lime, zinc and boron on yield and uptake of micronutrients by soybean

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Summary

In order to study the effect of lime zinc and boron on soybean yield and uptake of micronutrients, a field experiment was conducted at Botany Farm, College of Agriculture, Dapoli, dist. Ratnagiri, in Konkan region of Maharashtra. The experiment was laidout in Randomized Block Design with three replications and the treatments included two levels of liming i.e. $\frac{1}{2}$ L.R. and 1 L.R in combination with soil and foliar application of Zn and B in combinations. The results of the experiment showed that the grain (25.52 q ha^{-1}) and straw (37.29 q ha^{-1}) yield of soybean was significantly increased due to application of 1 LR + Zn + B through soil and foliar spray along with RDF. The application of RDF + 1 LR + Zn and B through soil and foliar spray showed maximum uptake of zinc (260.10 g ha^{-1}) by grain and (375.65 g ha^{-1}) by straw. While the uptake of boron was significantly higher (75.51 and 105.31 g ha^{-1}) in grain and straw, respectively due to application of RDF + $\frac{1}{2}$ LR + B through soil and foliar spray. The uptake of Cu, Fe and Mn was significantly higher in treatment consisting RDF + $\frac{1}{2}$ LR + B through soil and foliar spray (T_7). At the same time, there was decrease in the uptake values of Cu, Fe and Mn when lime dose was increased from $\frac{1}{2}$ LR to 1 LR The uptake of micronutrients by soybean was favourably improved by application of boron + $\frac{1}{2}$ LR along with RDF.

Key words : Lime, Zinc, Boron, Soybean, Yield, Micronutrient uptake

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Introduction

Soybean is an environment friendly grain legume and has now become a major source of protein, oil and health promoting phyto-chemicals for human nutrition and livestock feed around the globe. Soybean cultivation also improves soil health because of its atmospheric nitrogen fixing ability and deep root system. India has a great potential for production and domestic utilization of soybean and its derivatives for health and economic benefits of the people of the country. The area harvested

under soybean in India is 10.91 million hectares with an annual production of 10.37 million Mt having average productivity 951 kg ha^{-1} . In Maharashtra, soybean is cultivated on 3.22 million ha of area with an annual production of 4.67 million Mt and the productivity is $1,450 \text{ kg ha}^{-1}$ (Anonymous, 2013). Soil acidity is a major constraint to cropping globally, in all temperate, subtropical and tropical regions of the world where high precipitation has been a dominant influence on the pedogenic development of the soil. In India, vast areas of land in the Himalayan region, the eastern and north-

eastern plains, peninsular region and the coastal plains under different agro-climatic situations of the country which receive high rainfall are affected by soil acidity. The acid soils occupy about 90 million hectares, constituting over one-fourth of total geographical area of the country. The extent of acid soils in Maharashtra is about 0.54 million hectare (Anonymous, 2012).

Liming the acid soils has been suggested as the best method to attain and maintain a suitable pH for the growth of a variety of crops. Benefits of liming include improvement in nitrogen fixation and availability of essential nutrients (Ca, P, Mo) and decreasing the solubility of toxic elements Al and Mn. Zinc and boron are the essential elements in plant growth and metabolism. Zinc exist in soil in different forms such as primary and secondary minerals, insoluble organic and inorganic precipitates, soluble organic complexes and exchangeable and adsorbed forms. However, boron exist in soil in the form of highly insoluble mineral tourmaline as well as organic and inorganic forms. In fact, both these elements are thought to be found deficient in soils of Konkan region. In Maharashtra, zinc and boron showed their deficiencies to the extent of 38.2 and 31.7 per cent of analysed soil samples, respectively. Regional variation in the content of DTPA extractable zinc in soils was observed. The DTPA extractable zinc ranged from 0.13 to 3.66 mg kg⁻¹ in soils of Konkan. Sixty one per cent of the analysed soils from Konkan region were deficient in boron (Malewar *et al.*, 2001).

Intense leaching due to high rainfall in Konkan region removes major portion of all the bases from the soil giving distinctly acid character. In order to overcome the constraints in the productivity of acid soils, the age old practice is to apply lime judiciously to correct the soil acidity. The use of lime is in no way less important than the application of chemical fertilizers since lime not only furnishes calcium to the plants but also induces greater availability and uptake of other plant nutrients. There is a scope to enhance the yield potential of crops by application of liming material such as lime stone and use of locally available and cost effective industrial wastes such as basic slag, oyster shell, paper mill sludge, pressmud etc. Although beneficial effects of lime application on various crops in acid soils are well known, the information regarding the effect of B and Zn in presence of lime in legume is not adequate. Considering this situation such studies are very much essential in the context of intensive farming approach. Therefore, in the

present study an attempt has been made to consider crops other than the rice for their response to lime.

Resource and Research Methods

A field experiment was conducted during *Kharif* season on lateritic soil of Botany Farm, College of Agriculture, Dapoli, the Konkan region of Maharashtra to study the influence of lime, zinc and boron on yield and uptake of micronutrients by soybean. The representative initial soil sample (0 to 22 cm depth) was collected from the field, processed and analysed by following the standard methods of analysis. Bulk density was determined by clod method as described by Black (1965). The measurement of wet aggregates was carried out with the help of Yoder's apparatus (3/4 inch stroke at 29 stroke per minute) by using 2.0, 1.0, 0.5, 0.25 and 0.106 mm sieves and results were expressed as Mean Weight Diameter (MWD) as described by Singh (1980). Maximum water holding capacity was determined by using Keen-Rackzowski circular brass boxes as described by Piper (1966). The pH and electrical conductivity was estimated by glass electrode pH meter and EC meter, respectively using soil:water suspension 1:2.5 (Jackson, 1973), organic carbon content by wet oxidation using Walkley and Black's titration method (Black, 1965), calcium carbonate by rapid titration method as described by Piper (1966). The available nitrogen was estimated by alkaline KMnO₄ method developed by Subbiah and Asija (1956), available phosphorus was extracted by NH₄F-HCl solution and the phosphorus in the extract was determined by spectrophotometer method (Bray and Kurtz, 1945), the available potassium was extracted by shaking with neutral normal ammonium acetate for 5 minutes (Hanway and Heidal, 1952) and potassium in the extract was estimated by flame photometer method (Tandon, 1993). Available sulphur in soil was extracted by using Morgan's solution *i.e.* sodium acetate extractant and was determined turbidometrically by using barium chloride on spectrophotometer at 420 nm as described by Chesnin and Yien (1950). Exchangeable calcium and magnesium were determined by Versenate titration method as given in U.S.D.A. Hand book number 60 (Anonymous, 1968). The available micronutrients (*viz.*, Fe, Mn, Zn and Cu) were extracted with 0.005 M DTPA (Diethylenetriamine penta acetic acid), 0.1M Triethenolamine and 0.01 M CaCl₂ (pH) 7.3 and determined with Atomic Absorption

Spectrophotometer as described by Lindsay and Norvell (1978) and available boron was determined by hot water soluble method using Azomethine-H reagent by colorimetric method using Spectrophotometer as described by Tandon (1993).

The experiment was laid out in Randomized Block Design with three replications and the treatments included two levels of liming *i.e.* ½ LR and 1 LR in combination with soil and foliar application of Zn and B singly or in combination. Lime requirement was determined using buffer solution (1:2) as described by Shoemaker *et al.* (1961). The liming material was obtained as byproduct of Rashtriya Chemicals and Fertilizers Ltd., Mumbai. Soybean var. MACS-13 was grown with 30 x 30 cm and harvested at complete maturity. Treatment wise grain and straw yield data have been expressed in q ha⁻¹. Plant and grain samples from each treatment were processed and digested in di-acid of HNO₃ and HClO₄ of 9:4 proportion and used for determination of micronutrients (*viz.*, Zn, Cu, Fe and Mn) analysed on Atomic Absorption Spectrophotometer following the method of Lindsay and Norvell (1978) and boron was estimated by using curcumin oxalic acid method on spectrophotometer described by Tandon (1993). The experimental data was statistically analysed by adopting the method given by Panse and Sukhatme (1967).

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Physico-chemical properties and nutrient status of initial soil :

The soil of the experimental plot was lateritic (Alfisol) and acidic in reaction. It was very high in organic carbon, moderately high in available N, low in available P₂O₅ and very high in available K₂O. The soil was sufficient in DTPA extractable micronutrients and deficient in available boron. The physico-chemical properties and nutrient status of initial soil sample are presented in Table 1.

The physico-chemical properties of initial soil were in conformity with the results obtained by Baber *et al.* (2015). These results also corroborate the findings of Salvi *et al.* (2015) who reported the physico-chemical properties and nutrient status of initial soil samples of sample of lateritic soils in coastal region of Maharashtra.

Yield of soybean :

The data pertaining to the grain and straw yield of soybean as influenced by various treatments is presented

Table 1: Physico-chemical properties and nutrient status of initial soil		
Sr. No.	Characteristics	Initial soil
1.	Bulk density (Mg m ⁻³)	1.45
2.	Mean weight diameter (mm)	1.52
3.	Maximum water holding capacity (%)	57.17
4.	pH	5.23
5.	Electrical conductivity (dS m ⁻¹)	0.165
6.	Organic carbon (g kg ⁻¹)	17.7
7.	Calcium carbonate (%)	0.42
8.	Exchangeable calcium [cmol(p ⁺)kg ⁻¹]	4.43
9.	Exchangeable magnesium [cmol(p ⁺)kg ⁻¹]	2.77
10.	Available nitrogen (kg ha ⁻¹)	467.33
11.	Available phosphorus (kg ha ⁻¹)	8.30
12.	Available potassium (kg ha ⁻¹)	484.21
13.	Available sulphur (mg kg ⁻¹)	9.65
14.	DTPA extractable Fe (ppm)	39.77
15.	DTPA extractable Mn (ppm)	106.27
16.	DTPA extractable Zn (ppm)	1.26
17.	DTPA extractable Cu (ppm)	1.99
18.	Hot water soluble boron (ppm)	0.18

in Table 2. It is observed that the grain and straw yield of soybean were significantly influenced by liming. The lowest value of grain (4.35 q ha^{-1}) and straw (10.23 q ha^{-1}) yield were obtained with absolute control. Recommended dose of NPK fertilizer in combination with lime and micronutrients still produced higher yields as compared to control as well as application of chemical fertilizer. Among the various treatments, treatment T_8 (RDF + 1 LR + Zn @ $20 \text{ kg ZnSO}_4 \text{ ha}^{-1}$ + B @ $5 \text{ kg Borax ha}^{-1}$ through soil application + Zn and B as foliar application @ $0.5\% \text{ ZnSO}_4$ and 0.1% borax, respectively) produced significantly higher yield as compared to all other treatments, which was followed by treatment T_5 (RDF + 1 LR + B @ $5 \text{ kg borax ha}^{-1}$ through soil application + 1 spray @ 0.1% borax at flowering time). The magnitude of response by soybean was more in case

of boron than zinc. These results suggest mutual synergism between Zn and B. Such synergistic effect of Zn and B on grain and straw yield of soybean was obtained by Malewar *et al.* (2001) and Goswami and Rama (2014). The treatment T_5 has showed its superiority over T_4 , which produced 21.20 q ha^{-1} grain and 31.27 q ha^{-1} straw yield. Shankhe *et al.* (2004) reported that foliar application of boron @ 0.5% borax + soil application of molybdenum @ 1 kg ha^{-1} with RDF resulted in highest kernel and straw yield of groundnut. Subramanian *et al.* (2005) attributed application of Zn + S + B + Mo @ $5 \text{ kg} + 40 \text{ kg} + 1.5 \text{ kg} + 0.5 \text{ kg}$, respectively recorded highest grain yield. The soybean grain yield was highest (2037 kg ha^{-1}) when the crop received 1.0 kg B ha^{-1} (Sarker *et al.*, 2002). The highest grain yield (22.65 q ha^{-1}) and straw yield (19.66 q ha^{-1})

Table 2 : Effect of application of lime, zinc and boron on grain and straw yield of soybean

Tr. No.	Treatments details	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1	Control (No fertilizer and no lime)	4.35	10.23
T_2	RDF (Recommended dose of fertilizer)	9.18	17.83
T_3	RDF + 1 LR (lime requirement)	15.65	23.96
T_4	RDF + 1 LR + Zn @ $20 \text{ kg ZnSO}_4 \text{ ha}^{-1}$ through soil + 1 spray @ $0.5\% \text{ ZnSO}_4$ at flowering time	16.03	24.14
T_5	RDF + 1 LR B @ $5 \text{ kg borax ha}^{-1}$ through soil application + 1 spray @ 0.1% borax at flowering time	21.20	31.27
T_6	RDF + $\frac{1}{2}$ LR + Zn @ $20 \text{ kg ZnSO}_4 \text{ ha}^{-1}$ through soil + 1 spray @ $0.5\% \text{ ZnSO}_4$ at flowering time	15.36	23.35
T_7	RDF + $\frac{1}{2}$ LR B @ $5 \text{ kg borax ha}^{-1}$ as soil application @ 0.1% borax at flowering time	21.05	30.99
T_8	RDF + 1 LR + Zn @ $20 \text{ kg ZnSO}_4 \text{ ha}^{-1}$ + B @ $5 \text{ kg borax ha}^{-1}$ through soil application + Zn and B as foliar application @ $0.5\% \text{ ZnSO}_4$ and 0.1% borax, respectively)	25.52	37.29
T_9	RDF + $\frac{1}{2}$ LR + Zn @ $20 \text{ kg ZnSO}_4 \text{ ha}^{-1}$ + B @ $5 \text{ kg borax ha}^{-1}$ through soil application + Zn and B as foliar application @ $0.5\% \text{ ZnSO}_4$ and 0.1% borax, respectively)	20.95	30.63
	S.E. \pm	0.74	1.01
	C.D.(P=0.05)	2.21	3.02

Table 3 : Effect of application of lime, zinc and boron on uptake of micronutrients by grain and straw of soybean

Tr. No.	Zn (g ha^{-1})		B (g ha^{-1})		Cu (g ha^{-1})		Fe (g ha^{-1})		Mn (g ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	40.16	91.84	4.27	9.48	11.98	28.57	142.09	327.24	29.58	74.11
T_2	91.36	165.31	10.38	19.65	27.72	58.02	293.17	554.70	55.30	118.78
T_3	152.93	217.15	22.57	29.74	35.44	61.23	471.18	696.59	83.49	141.16
T_4	164.32	235.62	28.13	38.98	32.91	57.93	330.11	474.64	77.05	129.29
T_5	200.35	254.14	58.41	80.61	40.93	66.63	466.66	635.26	90.29	151.77
T_6	168.25	250.21	30.54	41.06	43.93	70.57	440.99	629.89	84.85	148.66
T_7	203.64	274.63	75.51	105.31	58.50	91.53	511.29	707.39	109.69	186.58
T_8	260.10	375.65	61.58	83.91	43.50	69.61	495.75	698.97	87.83	158.19
T_9	220.60	316.35	66.49	90.88	52.06	83.15	479.37	648.19	107.47	170.53
S.E. \pm	7.16	11.34	2.30	3.10	1.52	2.58	19.49	26.72	4.39	6.94
C.D. (P=0.05)	21.47	33.99	6.90	9.29	4.56	7.73	58.43	80.12	13.15	20.80

was observed in treatment receiving foliar spray of zinc and iron in combination (Sale and Nazirkar, 2013).

Uptake of micronutrients :

Uptake of zinc :

The uptake of zinc by grain and straw of soybean (Table 3) as affected by different treatments revealed that application of increasing dose of lime in combination with zinc and boron resulted into corresponding and significant increase in zinc uptake by grain and straw of soybean over control. Maximum zinc uptake was noted in the treatment T_8 receiving NPK + 1 LR + Zn @ 20 kg $ZnSO_4$ ha⁻¹ + B @ 5 kg borax ha⁻¹ through soil application + Zn and B as foliar application @ 0.5 % $ZnSO_4$ and 0.1 per cent borax, respectively followed by the treatments (T_9) receiving NPK + ½ LR + Zn @ 20 kg $ZnSO_4$ ha⁻¹ + B @ 5 kg borax ha⁻¹ through soil application + Zn and B as foliar application @ 0.5 % $ZnSO_4$ and 0.1 per cent borax, respectively. It is evident from the above data that the treatments where B is applied along with Zn and lime the uptake of Zn is increased. Even B alone with lime increased the uptake of Zn by soybean indicating synergistic interaction between Zn and B. The above results are in conformity with Malewar *et al.* (2001) who reported that the interactive effects between zinc and boron were additive in increasing their uptake by mustard indicating highest uptake of zinc in 30 kg $ZnSO_4$ × 10 kg borax ha⁻¹ followed by 30 kg $ZnSO_4$ × 5 kg borax ha⁻¹ treatment combinations. The results were also in accordance with the results reported by Sale and Nazirkar (2013) and Kobraee and Shamsi (2014).

Uptake of boron :

The perusal of the data as a result of application of recommended NPK, lime, zinc and boron it is observed that, B uptake by soybean (Table 3) increased with the application of B through borax through soil and foliar spray as in treatment T_7 , T_9 , T_8 and T_5 . At the same time, application of lime @ 1 LR (T_8 and T_5) decreased the B uptake by soybean as compared to ½ LR (T_7 and T_9). Liming (½ LR) with recommended NPK + B @ 5 kg borax ha⁻¹ through soil application + 1 spray @ 0.1% borax at flowering (T_7) recorded maximum values of B uptake *i.e.* 75.51 g ha⁻¹ and 105.31 g ha⁻¹ by grain and straw of soybean, respectively. The uptake of boron by grain and straw increased gradually with the application of zinc, boron, along with decreasing doses of lime individually or in combination. However, it was sharply

curtailed when the liming ($CaCO_3$) doses increased to double. The present findings are also supported by the work of Shankhe *et al.* (2004). The application of different levels of boron resulted in a linear increase in boron in leaf tissues of soybean plant Aziz and Aly (2012).

Uptake of copper :

The data revealed that full dose of liming with micronutrient application significantly decreased the uptake of copper by grain and straw of soybean (Table 3). The lowest Cu uptake by grain and straw was observed in absolute control treatment. Application of recommended dose of NPK fertilizer increased Cu uptake significantly (27.72 g ha⁻¹ for grain and 58.02 g ha⁻¹ for straw) over control. Treatment T_7 (RDF + ½ LR + B @ 5 kg borax ha⁻¹ through soil application + 1 spray 0.1 % borax at flowering time) resulted into highest (58.50 g ha⁻¹ and 91.53 g ha⁻¹) uptake of copper by grain and straw of soybean, respectively, followed by treatment T_9 . These results are in conformity with that of Singh *et al.* (1993).

Uptake of iron :

It is observed from the data that iron uptake (Table 3) was 142.09 g ha⁻¹ by grain and 327.24 g ha⁻¹ by straw of soybean in the control plot. Addition of N, P and K through urea, single super phosphate and muriate of potash significantly increased the iron uptake by grain and straw. Significantly highest iron uptake was noted in case of grain due to application of recommended dose of NPK + ½ L.R. + B @ 5 kg borax ha⁻¹ through soil + 1 spray @ 0.1 per cent borax at flowering (T_7). The results were in conformity with the results reported by Sale and Nazirkar (2013).

Uptake of manganese :

The data revealed that application of recommended doses of NPK fertilizer along with Zn and B with increasing doses of lime resulted into corresponding and significant increase in manganese uptake (Table 3) by soybean crops (grain and straw), over no fertilizer and no liming (control). In general the uptake values of Mn decreased with increasing the dose of lime. ½ dose of L.R. + RDF + B @ 5 kg borax ha⁻¹ through soil application + 1 spray @ 0.1 % borax at flowering (T_7) was significantly superior in Mn uptake by grain and straw (109.69 g ha⁻¹ for grain and 186.58 g ha⁻¹ for straw) in uptake over all other treatments except T_9 which was at

par with the treatment. The results were also in accordance with the results reported by Kobraee and Shamsi (2014).

Conclusion :

The application of RDF + 1 LR + Zn @ 20 kg ZnSO₄ ha⁻¹ + B @ 5 kg borax ha⁻¹ through soil + Zn and B as foliar application @ 0.5 % ZnSO₄ and 0.1 % borax, respectively found to be beneficial for maximizing the yield and maximum uptake of zinc by grain and straw. While the uptake of boron was significantly higher in grain and straw due to application of RDF + ½ LR + B through soil and foliar spray (T₇). The uptake of Cu, Fe and Mn was significantly higher in treatment RDF + ½ LR + B through soil and foliar spray (T₇). At the same time there was decrease in the uptake values of Cu, Fe and Mn when lime dose was increased from ½ LR to 1 LR. The uptake of micronutrients by soybean was favourably improved by application of boron + ½ LR along with RDF.

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